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THE WEST INDIAN PEASANT AND MIXED FARMING

INCREASING attention has been paid of late years to the problem of improving the standard of agriculture throughout the British West Indies. In common with many other countries these colonies have suffered and are still suffering from the effects of land exploitation. Practically everywhere there are signs of soil erosion and even in those islands where attempts have been made to preserve the natural forest and land resources the visitor will see denuded hill sides and shifting cultivation. In some hilly districts the problem is more serious still as the land has deteriorated so much that it is almost beyond repair. There can be little doubt that this is due to poor and wasteful methods of farming. For years, a system essentially involving single crop cultivation and which has to a large extent been dictated by the necessity for producing export cash crops, has been practised. Under this system the land has been cropped repeatedly, often without proper manuring, and in many districts the soil has been robbed of much of its natural fertility. Fortunately, it seems that the lessons of soil conservation are at last being learnt and that agricultural systems are being slowly evolved which instead of exhausting the soil, will gradually build up fertility and stabilize the land.

It will be obvious that in any programme of agricultural reform considerable attention will have to be devoted to the reorganisation of peasant agriculture. The agricultural practices of the West Indian peasant are, as a general rule, very crude and his level of production correspondingly low. There is room undoubtedly for an immense improvement in his present methods of husbandry. Even on some of the best small holdings no system of cropping is apparent. As already stated, peasant land, like most other land in the West Indies has been exploited for growing cash crops for export. As long as these crops could be grown without too much trouble and in sufficient quantities and at prices which would provide the owner with a living, it did not matter, as far as he was concerned, in what state of fertility the land was left. Whenever prices fell, however, the effect on the agricultural population was serious. It seems logical therefore that to guard against external fluctuations in the prices of export produce the peasant should, in addition to growing cash crops, also grow sufficient food

crops for himself and his family. This will certainly involve radical changes in the existing systems of agriculture. In the first place shifting cultivation will have to stop and a change to a system of agriculture in which crop and stock production are combined and which would also involve a proper rotation of crops, would seem essential. The main objectives would be a more balanced economy and a measure of self-sufficiency for the peasant family.

A profitable system of mixed farming on the lines indicated can only be evolved by experimentation and trial. We do not know, for instance, with anything approaching certainty, what the economic size of a holding should be or what fractions of it should be devoted to food and export crops or how much stock a peasant should keep. The size of holding that has generally been recommended and adopted in most land settlement schemes has been between five and seven acres. This area, however, has proved altogether too large for peasants cultivating their land with hand implements, which is the peasant's universal practice in the West Indies. Figures recently published in this Journal* suggest that the area such a family can cultivate efficiently lies somewhere between one and a half and two and a half acres. Even if this were a conservative estimate, it is quite clear that the figure must be much less than five acres. To give the peasant more land than he can handle is almost worse than to give him less than will suffice to feed and clothe him. For with too big an area he inevitably adopts the extensive slipshod methods of cultivation which soon lead to the depreciation of all his land. If the land settlement scheme included—which none in the West Indies has yet done—the provision of draught cattle and a plough and a "horse-hoe" for the peasant, then perhaps five to seven acres might have been a more reasonable figure. It has been calculated that four to five acres would be reasonable under these circumstances, but these figures are based on rather a small number of working days per year, and comparison with West Africa and India, in both of which countries the normal area for a peasant with one plough is 12 or 13 acres, would suggest that in the West Indies six or seven would be a minimum figure if full economic use is to be made of the cattle, especially since the stock of such a peasant should obviously include a cow, either instead of one of the bullocks or in addition to them.

Incidentally, these figures serve to show the vast economic importance to the peasant of a plough and a hoe and the cattle to draw them, provided always that he has enough land to be able to use such implements effectively, and provided also that the land is not too steep to make implemental tillage impossible—provisoes which unfortunately rule out many districts in the West Indies. For it must be remembered that if he conserves his manure and uses it properly, the land of a peasant who has a plough, in addition to supporting his cattle, should grow more human food or more cash crops than could be grown per acre if no stock were kept. That is shown by the experience of every heavily populated country in the world: the more people the land has to support, the more stock it must also support to enable it to feed those people.

Considerable saving in the peasant's time and effort should be effected through his adopting a system of mixed farming which would essentially be based on feeding his cattle on cultivated grasses because these provide such a convenient means of feeding cattle in the wet tropics, give such high yields per acre and can be so effective in preventing soil erosion and, when established, need so little cultivation.

In the settlement of peasants the question of the form of land tenure deserves very serious consideration. In many of the land settlement schemes started during the last 30 or 40 years, freehold tenure has been tried and proved disastrous. In every scheme the experience has been the same. While the peasants are paying off the instalments of the purchase price, the prospects for the success of the schemes seemed fairly promising. The peasants were working hard, accepting the advice of their settlement and agricultural officers and gradually improving their cultivations. From the date that the instalments had been paid off the land began to pass into the hands of mortgagors and absentee landlords. In a very few years all prospects for the real success of the schemes had vanished. In many West Indian islands the landlords themselves have introduced systems of yearly tenancies or share cropping, both of which have led to land exploitation in the worst form. It is clear that if land settlement in the West Indies is to succeed, a well considered form of leasehold tenancy must be introduced, which will not only give the peasant adequate security of tenure and ensure him compensation for improvements in the event of the termination of the lease, but also at the same time rule out all possibility of the holding passing to mortgagors or being excessively sub-divided. A satisfactory system of tenure will not make a land settlement scheme necessarily successful: many other factors are also essential. But a suitable system of tenure is the first essential, without which there can be no hope of success.

The strenuous efforts which have been made recently to stem the swelling tide of soil erosion and to arrest the tendency towards inefficient agricultural methods must be maintained. The need for a more self-contained agriculture in war time is universally recognised but a comprehensive soil conservation policy is equally desirable and both should go hand in hand. In planning, therefore, to meet the war time problem of a threatened food shortage it would be a tragedy if we lost sight of the all time problem of soil conservation. It will, on the other hand, be a triumph of common sense if each is made to solve the other.

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UNIFORMITY TRIALS ON ESTATE CACAO FIELDS IN GRENADA, B.W.I.

BY

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Introduction

A series of manurial experiments has been instituted in Grenada in connection with a cacao rehabilitation scheme. The experiments were laid out primarily because of the paucity of reliable information on manurial responses, in spite of the widespread use of both artificial and organic manures in the ordinary plantation practice of the island. Obviously for a rehabilitation scheme which is designed to increase yields per acre, information about manuring is essential.

The lack of reliable information is not due so much to the absence of experiments themselves as to the absence of conclusive results from them. Cacao as cultivated in Grenada is most unsuitable material on which to conduct experiments for the following reasons: (i) there is an extremely wide variation in the yield on individual tree sites due to age of tree, its environment, its genetic make up, etc.; (ii) cacao is a tree crop which probably responds slowly to most treatments and which also bears the relics of past treatment and mal-treatment. Ideal experimental material would consist of a flat or uniformly graded field consisting of trees of uniform age and growth, vegetatively reproduced from one (or similar) clones; on such material undoubtedly more precision could be obtained than an ordinary plantation field of seedlings. But since it would take at least ten or probably as many as thirty years for a special experimental field to reach sufficient maturity, existing fields of seedlings are the only available material at the present time. It was therefore considered necessary in planning these manurial experiments to try and make them fulfil the double purpose of providing information not only about manurial responses but also about the best type of lay-out for field conditions.

Yields were obtained by calculating the yield of individual trees by three monthly pod countings. This method is open to some error but in plots where a number of yields are summed the errors are probably small and all of a similar nature. These yields have already been obtained for the two control years 1940-41 and 1941-42; the manures were applied in April, 1942, so that the responses will first appear in 1942-43.

It is proposed in this article to examine the precision of the experiments from the yields in 1940-41 and 1941-42. It is hoped that this examination will afford a record which will be useful to future investigations. Although these particular experiments cannot now be redesigned they are for these two years in the nature of a uniformity trial.

Experimental Designs

Experiments have been laid out on eleven fields as shown in Table I. Individual experiments cover an area varying from slightly over 2¼ acres to about 1½ acres. Area (from about 1/12 to 1/7 acres) was taken as the measurement of plot size in all but two experiments (Fields 5A and 13A), in which an individual tree was used as a unit. Seven of the fields were laid out in single 4 × 4 Latin Squares, four of them having each of the sixteen plots divided in two so that a fifth treatment was superimposed on the original square. It was (wrongly) assumed, when design was first considered that in spite of increased replication the half plots might be too small to give good precision, but on a trial division of certain fields this was found not to be so. Furthermore the 4×4 with half plots allows a comparison of all eight combinations of four treatments whereas the 5×5 Latin Square without half plots allows only five. It is anticipated further that

TABLE I

Design of Manurial Experiments

Field Code	Type of Experiment	Plot Size (Acres)	Design
14 A	N,P,K, and Combinations	1/8 (.1266)	4 × 4 Latin Squares with Half Plots.
65 A	do. do.	1/9 (.1056)	
47 A	do. do.	1/11 (.0926)	
64 A	Rates of Pen Manure and Forking	1/12 (.0845)	
36 A	Pen versus Artificials	1/7 (.1446)	4 × 4 Latin Squares.
30 A	do. do.	1/9 (.1056)	
37 B	Rates of Superphosphate	1/11 (.0918)	
25 A	N,P,K.	1/9 (.1116)	5 treatments × 4. Randomized Blocks.
66 A	Pen versus Artificials	1/12 (.0803)	
5 A	P, K, and Combination	Single Trees	4 Treatments × 52.
13 A	Lime, P and Combination	Single Trees	4 Treatments × 49.

the 4×4 Latin Square with half plots will give results better adapted to the particular treatments that have been applied; three of the four are artificial manure experiments and (according to the soil analyses) small responses are to be expected from one of the manures (either nitrogen or potash); the manures likely to give a small response have been allotted as half plot treatments on which greater precision because of more replication is justifiably expected. On the fourth field (64A) three rates of pen manure are being compared and on the half plots the effect of forking; forking cacao fields is a characteristic of Grenada cultivation and is for that reason worthy of test; but from the nature and effect of the operation a high degree of experimental precision will be required to detect any real effects.

The plots on three of the Latin Square experiments were not subdivided partly for comparison of layout and partly because of the irregular topography and planting of the fields.

The randomized blocks were laid out on two fields mainly because the shape of the fields did not lend itself to a Latin Square design. Field 25A is a relatively long narrow strip so that a Square would have utilized only part of the field or the plots would have consisted of long narrow strips with a correspondingly large number of guard row trees. It is interesting to note, however, how deceptive a cacao field can be and how accepted principles of design must be tested wherever possible: with no actual yield data available it would be supposed in a field similar to 25A that the lay-out most likely to be effective would be four treatments replicated in five blocks along the longest side of the rectangle; actually it was found from a yield analysis that a more effective lay-out was five treatments replicated in four blocks; there was in fact a wider variation along the short side of the rectangle than along the longer side.

Field 66A is L-shaped so that for an experiment on an area plot basis the randomized block is the only feasible design.

In fields 5A and 13A single trees were selected and treated as plot units. Trees were selected for uniformity in appearance, environment and yield. To safeguard against overlapping of treatments no adjoining trees were selected. Approximately 200 trees were selected in this way from each field of 1,000 pickets. Four treatments were randomized, and the treatments applied to trees individually.

From the statistical point of view the single tree lay-out would be considered superior to the area plot designs used in these experiments because the single trees have been selected for uniformity and the treatments replicated many more times than in the plot designs. How far the single tree experiments are superior statistically to the others can be seen below but it must be pointed out that the single tree design has very definite agricultural disadvantages. First, it is unsound to translate the applications per tree into quantities per acre; however carefully the manures are applied it is impossible to ensure that the whole of the application is available for the selected tree and that none is taken up by surrounding unselected ones. The second disadvantage is that it is difficult to translate any yield increments obtained into agricultural terms; it is obviously unsound to multiply the increments on the selected trees by the average number of all types of trees in an average field; indeed, it is impossible from such an experiment to tell what increments are likely to be obtained from any but the selected population.

The single tree design is in fact not suited to experiments in which quantitative results are required; from this lay-out it will probably be possible to state with a relatively high degree of precision which treatments result in higher yields but it will not be possible to state what increments per acre have been obtained or for that matter what applications per acre have been made. This design appears to be particularly well adapted for a preliminary reconnaissance to discover which treatments are worthy of quantitative experimentation.

Plot Size

The total variation per plot is set out according to plot size in Table II. It is obvious from this Table that there are wide differences between these fields both in average yield and in plot variation. These differences do not appear to be correlated with plot size, age of field or average yield. The only general difference in variability with plot size seems to be that the coefficient of variation increases in plots of less than about .08 acres (1/12 acre); if treatments are expected to influence yields proportionally the larger plot is to be preferred; if treatments are expected to influence yield irrespective of basic yields there is no objection to plots of as small as 1/25 of an acre which of course will result in considerable economy of experimental material.

Table III has been constructed to test whether plots larger than about 1/7 acres are less variable than the sizes shown in Table II. Many experiments with cacao in the West Indies have consisted of large plots, and it is therefore interesting to see whether there is any inherent advantage in large plots. Table III was calculated by adding pairs of plots of experiments in Table II thus converting a 4×4 into a 2×4 and so on. There seems little object in showing plots over about 1/3 of an acre, since with larger plots little replication could be obtained.

It seems clear from Table III that the larger plots, although somewhat less variable, do not gain sufficiently in this respect to compensate for the increase in experimental material required.

The conclusion with regard to plot size, therefore, seems to be that on the whole the small plot is preferable. The most suitable size appears to be about 1/10 of an acre, on which a 25 per cent.

TABLE II

Total Variation in Yield per Plot arranged according to Plot Size

Field Code	Design	Plot Area (Acres)	Age of Field 1940-41	Average Yield per Plot (Lbs.)	Standard Deviation (Lbs. per plot)	Coefficient of Variation Per cent.
36 A	4 × 4	1/7 (.1446)	55	87.4	14.26	16.4
14 A	4 × 4	1/8 (.1226)	27	65.2	18.33	28.2
25 A	5 × 4	1/9 (.1116)	35	96.5	33.36	34.8
65 A	4 × 4	1/9 (.1056)	55	47.9	16.45	34.6
30 A	4 × 4	1/9 (.1056)	40	62.9	15.32	24.3
47 A	4 × 4	1/11 (.0926)	50	52.6	12.33	23.4
37 B	4 × 4	1/11 (.0918)	40	76.6	22.36	29.3
64 A	4 × 4	1/12 (.0845)	60	26.8	10.33	38.4
66 A	5 × 4	1/12 (.0803)	22	24.9	10.16	40.6
14 A	2 × 16	1/16 (.0633)		32.6	13.30	40.8
65 A	2 × 16	1/20 (.0528)	see	23.9	11.90	49.8
47 A	2 × 16	1/22 (.0463)	above	26.3	7.84	29.9
64 A	2 × 16	1/24 (.0423)		13.4	6.33	47.2

TABLE III

Total Variation in Yield per Plot. (Plot Size 1/6 Acres—1/3 Acres)

Field Code	Plot Area (Acres)	Average Yield per Plot (Lbs.)	Standard Deviation (Lbs. per Plot)	Coefficient of Variation. Per cent.
36 A	1/3 (.2892)	174.8	19.18	11.0
14 A	1/4 (.2452)	130.4	20.38	15.6
25 A	1/5 (.2232)	192.9	56.25	28.6
65 A	1/5 (.2112)	95.8	21.46	22.4
30 A	1/5 (.2112)	125.8	26.38	21.0
47 A	1/5 (.1852)	105.3	17.61	16.8
37 B	1/5 (.1836)	153.2	43.51	28.4
64 A	1/6 (.1690)	53.6	18.89	35.3
66 A	1/6 (.1606)	45.8	13.27	29.0

variation is to be expected, but it must be remembered that plots of smaller size are not unsuitable if the smaller size is compensated for by correspondingly more replication.

It should be pointed out that these eleven fields have been selected out of an available 26 because of their comparative uniformity. Wider variation could be expected from other less uniform fields. Nevertheless, a field that may appear from inspection to be uniform does not always prove to be so on analysis. For instance, fields 14A, 25A, 66A and 65A are fields of uniform appearance and yet the yield variation is as high or higher than the average; fields 36A, 47A, and 64A, are of irregular appearance and yet the actual variation is not exceptionally high. The reason for the misleading appearance of a field is the tremendous variation in the yields of individual tree sites: thus, an area with many unoccupied sites gives the impression of low yield, whereas the few trees that are on the area may be giving a very high yield.

An excellent example of the lack of correlation between tree number and yield is furnished by Field 64A. In Table IV three half plots with the highest and three with the lowest number of trees are shown with the corresponding 1940-41 yields. If there is any difference, the half plots with the lowest numbers of trees yield more than the thickly populated areas.

TABLE IV

Number of Trees and Total Yield on Six Selected Half Plots on Field 64A.
(1/2 Plot Area=1/24, (.0423) Acres)

	Number of Trees	Total Yield (1940-41) (Lbs.)
Densest Populations ...	26	6.0
	21	5.9
	18	10.1
Sparsest Populations ...	8	9.4
	7	11.4
	5	6.3

Analysis of Variance

The total variances were allotted in the orthodox manner to rows, columns (blocks in randomized blocks), treatments and error. The errors for the two crop years 1940-41 and 1941-42 expressed in various ways are given in Table V. The Table shows the superiority of Latin Squares over Randomized Blocks in the reduction of total variation but even more striking is the difference between fields of Latin Squares and between years on the same field. As much as 93 per cent. and as little as 50 per cent. of the total sum of squares may be accounted for on different fields of Latin Squares; as much as 80 per cent. and as little as 60 per cent. may be accounted for on one field in two years. Although it may be said that about 70 per cent. of the plot variation can be accounted for with the Latin Squares and about 50 per cent. in the 5×4 Randomized Blocks there is wide fluctuation from these percentages.

The errors for the half plots on the four subdivided Latin Squares were also calculated and are presented in Table VI; these errors are the variations unaccounted for by all whole plot variations (including errors), and by half plot treatments and interactions.

The standard deviations of the half plot errors are of about the same absolute magnitude as for the whole plots, so that the coefficients of variation are about double. There is also wide fluctuation from field to field though the difference from year to year does not seem as great as for the whole plots.

The significant differences calculated from these errors are given in Table VII; ($\sqrt{\text{Error variance}} \times n \times 2 \times t$); for simplicity a 5 per cent. level of significance only has been taken.

Among the Latin Squares the significant differences vary from 122.9 lbs. to 249.2 lbs. per acre and from 20.3 per cent. to 68 per cent. of the mean yield. These variations are very wide, and point to the conclusion that the degree of precision of an experiment of this design is to a great extent a matter of chance; from these fields there is little or no indication as to their suitability from appearance alone. Further it appears that one year's yield is not necessarily a reliable guide to its suitability in another year; for instance field 37B showed relatively high precision in 1940-41 and field 64A relatively low; in 1941-42 there is little difference between these two fields.

TABLE V

Error Variation for 1940-41 and 1941-42 Crops

Field Code	1940-41 Error as:			1941-42 Error as:		
	Per cent. of Total Sum of Squares.	Standard Deviation (Lbs.)	Coefficient of Variation (Per cent.)	Per cent. of Total Sum of Squares.	Standard Deviation (Lbs.)	Coefficient of Variation (Per cent.)
4 × 4 Latin Squares						
36 A	20.8	10.3	11.7	41.9	13.3	21.4
14 A	31.6	16.2	24.8	15.5	9.9	25.2
65 A	13.9	9.7	20.2	30.3	14.3	28.6
30 A	16.2	9.7	15.5	28.8	8.5	20.8
47 A	46.8	13.3	25.2	No Yields Available.		
37 B	6.7	9.2	12.0	19.8	12.4	24.6
64 A	42.4	10.7	40.2	21.2	8.9	27.6
5 × 4 Rand. Blocks						
25 A	54.9	31.2	32.4	55.6	27.8	33.6
66 A	63.1	10.1	40.6	No Yields Available.		

TABLE VI

Error Variation for 1940-41 and 1941-42 Crops of Half Plots

Field Code	1940-41 Error as:			1941-42 Error as:		
	Per cent. of Total Sum of Squares.	Standard Deviation (Lbs.)	Coefficient of Variation Per cent.	Per cent. of Total Sum of Squares.	Standard Deviation (Lbs.)	Coefficient of Variation Per cent.
14 A	27.3	15.8	48.0	25.8	11.7	59.6
65 A	47.8	18.7	78.4	33.8	13.6	54.5
47 A	22.6	8.5	32.3	No Yields Available.		
64 A	23.8	6.6	49.3	17.2	8.3	51.6

From Table VII it appears that the 5×4 Randomized Blocks are inferior to the 4×4 Latin Squares. If Randomized Blocks are to be used and data is not available for control years of no treatment, it is desirable to have more than four replications of each treatment.

The 2×16 half plots give the lowest significant differences. The relatively large difference on field 65A in 1940-41 is probably fortuitous since it is very much reduced in 1941-42. It appears that this design can be relied upon to give significant differences of about 130 lbs per acre or between 25 and 30 per cent. of the mean yield.

It should perhaps be pointed out that these differences are the minimum at a 20 to 1 chance necessary to show that some response is to be expected in other similar trials; not that it is profitable to apply the treatment. In the practical interpretation of differences it may be more important to express the differences at a lower level of significance with the object of deciding whether a treatment is likely to be profitable. It would probably mean more to the agriculturist to know that there was, say, a 6 to 1 chance of a treatment being profitable than that there was say a 20 to 1 chance of some response being obtained.

Analysis of Covariance

It was hoped, when these experiments were designed, that the analysis of covariance of errors (after taking account of rows, columns, etc.) would greatly increase precision. It was supposed that much of the error variance was due to the incidence of large field drains, groups of blank pickets, large shade trees and other similar local conditions which would permanently influence the relative yield of the plot. It can be seen, however, from Table VIII the analysis of covariance did not reduce the 1941-42 variance very markedly on the whole plots. Indeed, if reference is also made to Table VII it will be seen that on only two whole plot Latin Square experiments (fields 14A and 30A) were the adjusted significant differences less than both of the two years 1940-41 and 1941-42 differences. On one whole plot experiment (field 64A) the adjusted difference was actually larger than the unadjusted one. On the half plots the adjusted differences are consistently below the unadjusted ones and it appears that with one control year available for covariance the difference with this design can be reduced to about 80 lbs. per acre on 20 to 25 per cent. of the mean yield. The contrast between whole and half plots emphasises the need for replication; with the four replications loss of one out of six degrees of freedom in the error necessary in adjusting for covariance outweighs to a great extent the deduction that can be made. It should perhaps be pointed out that there is a big and probably exceptional difference in the two seasons to which the data refer. The adjustments that have been made are therefore likely to be smaller (1) than in two more normal years.

It is unfortunate that yields on both of the Randomized Blocks are not available for 1941-42, since it is striking how the difference on field 25A is reduced by adjustment. On this field the difference is reduced from a high figure to as low

TABLE VII

Significant (P=.05) Differences for 1940-41 and 1941-42 Crops

Significant Difference as :	d/f of Error	1940-41		1941-42	
		Lbs. per Acre	Per cent. of Mean Yield	Lbs. per Acre	Per cent. of Mean Yield
4 × 4 Latin Squares.					
36 A	6	122.9	20.3	159.2	36.5
14 A	6	222.4	43.2	135.1	43.5
65 A	6	158.6	35.0	234.3	49.6
30 A	6	159.2	26.7	139.0	35.7
47 A	6	249.2	43.8	No Yields Available	
37 B	6	172.5	20.7	231.2	42.5
64 A	6	219.6	68.0	183.2	48.1
5 × 4 Rand. Blocks.					
25 A	12	429.7	49.7	383.8	51.7
66 A	12	194.6	62.7	No Yields Available	
2 × 16 Half-Plots.					
14 A	12	136.1	26.4	101.1	32.6
65 A	12	192.9	43.0	141.0	29.8
47 A	12	99.8	18.0	No Yields Available	
64 A	12	85.7	26.5	107.2	28.2

TABLE VIII

Significant (P=.05). Differences of 1941-2 and 1941-2 adjusted by 1940-41 Crops

Significant Difference as :	d/f of Error	1941-2. Lbs. per Acre	1941-2. Per cent. of Mean Yield	Correlation Coeff.	d/f of Error	1941-2 adjusted by 1940-41 Lbs. per Acre	1941-2 adjusted by 1940-41 Per cent. of Mean Yield
4 × 4 Latin Squares.							
36 A	6	159.2	36.5	+.71	5	129.9	29.8
14 A		135.1	43.5	+.89	5	71.6	23.1
65 A	6	234.3	49.6	+.56	5	223.0	47.2
30 A	6	139.0	35.7	+.87	5	78.7	20.2
47 A	—	No Yields Available					
37 B	6	231.2	42.5	+.73	5	183.4	33.4
64 A	6	183.2	48.1	+.71	5	191.6	50.3
5 × 4 Rand. Blocks							
25 A	12	383.8	51.7	+.92	11	159.7	21.5
66 A	—	No Yields Available					
2 × 16 Half-Plots.							
14 A	12	101.7	32.3	+.77	11	67.5	21.8
65 A	12	141.0	29.8	+.97	11	37.4	7.9
47 A	—	No Yields Available					
64 A	12	107.2	28.2	+.69	11	81.5	21.4

TABLE IX

Variation in Yield per Tree on "Single Tree" Experiments

Field Code :	1940-41 (Selection Year) Average Yield per tree (Lbs.)	Standard Deviation (Lbs.)	Coeff. of Variation Per cent.	Correlation Coeff.	1941-42. Average Yield per Tree (Lbs.)	Standard Deviation (Lbs.)	Coeff. of Variation Per cent.
5 A ...	2.06	1.02	49.5	+.62	2.17	1.45	66.8
13 A ...	2.62	1.76	67.0	+.66	2.00	1.92	96.4

as the average Latin Square. It may be that the deficiency of the Randomized Block design of taking account of yield variation in one direction only may be compensated for by using the covariance analysis; it is possible that by utilizing yields in a control year the randomized block is as precise as the Latin Square. This observation must however at present remain unconfirmed, and may be entirely fortuitous.

Single Tree Lay-out

The selection standards used for the two fields with single tree lay-out were 5A: 4¼ lbs. to ½ lb. per tree, 13A: 5¼ to ½ lb. per tree; all trees were of uniform appearance and age, and none of them was adjoining. In field 5A, 208 trees were obtained; in field 13A, 196; both are fields of 1,000 pickets. It may be pointed out that theoretically it would be possible to obtain 250 trees not adjoining each other from a field of 1,000 so that although these standards allowed some latitude in selecting individual trees, the standards were not very severe. It is important to note in Table IX that the variation in yield in the year after selection was almost as great as the variation in unselected trees (the coefficient of variation for all 20,000 trees recorded in the Scheme is about 100 per cent.)

In the selection year (1940-41) the differences required for significance with four treatments (at P=.05) were naturally small; Field 5A, .40 lb. per tree, field 13A, .51 lbs. per tree, both about 19 per cent. of the mean yields. In the second year the differences had risen to: field 5A, .56 lbs. or 26 per cent. of the mean yield, and field 13A, .55 lbs. or 27 per cent. Evidently, with these selection standards and without the use of a covariance analysis the single tree lay-out has no great advantage over a plot lay-out consisting of 10 to 20 replications.

TABLE X

Significant (P=.05). Differences, etc. for 1941-2 on Different Standards of Tree Selection

Selection Limits 1940-41 Yield Lbs. per tree.	Field 5 A.				Field 13 A.			
	Replications*	Mean Yield (Lbs.)	Sig. Diff. Lbs. Tree	Sig. Diff. % of Mean	Replications*	Mean Yield.	Sig. Diff. Lbs. Tree	Sig. Diff. Per cent. of Mean
½—4¼	52	2.17	.56	25.7	—	—	—	—
½—5¼	—	—	—	—	49	2.00	.55	27.4
¾—4¾	—	—	—	—	42	1.94	.56	29.0
¾—4¼	—	—	—	—	37	1.73	.48	27.5
¾—3¾	40	2.23	.62	27.9	31	1.63	.37	23.1
1¼—3¼	23	2.31	.80	34.7	21	1.57	.60	38.2
1¾—2¾	11	2.40	1.33	55.5	5	1.52	1.29	84.9

* The four treatments were not re-randomized over all the available trees at any selection limit. Somewhat more replication particularly in the narrowest limits could be obtained if this were done.

TABLE XI

Significant (P=.05). Differences for Two Treatment Experiments. (1941-42)

Selection Limits 1940-41 Yields Lbs. Per tree.	Field 5 A.				Field 13 A.			
	Replications*	Mean Yield (Lbs.)	Sig. Diff. Lb. Tree	Sig. Diff. % of Mean	Replications*	Mean Yield	Sig. Diff. Lb. Tree	Sig. Diff. Per cent. of Mean.
½—4¼	104	2.17	.39	18.0	—	—	—	—
½—5¼	—	—	—	—	98	2.00	.39	19.3
¾—4¾	—	—	—	—	84	1.94	.39	20.5
¾—4¼	—	—	—	—	74	1.73	.34	19.4
¾—3¾	80	2.23	.44	19.7	62	1.63	.27	16.3
1¼—3¼	46	2.31	.80	34.7	42	1.57	.42	27.1
1¾—2¼	22	2.40	.96	40.2	10	1.52	.91	59.5

* See note Table X.

It seems desirable, therefore, to investigate whether the limits of yield used in making the selection were the most effective for experimentation. It does not seem necessary to increase the tolerance of selection, but there is a possibility that narrower selection limits would give a more precise experiment or equal precision for less labour. Table X presents the results of reselecting the trees on these two fields on the assumption that four treatments are to be applied.

It can be seen from the Table that a more rigid limitation of yield in the selection year would not materially improve the experiments. On field 13A it appears that some improvement could have been obtained by restricting the selection to ¾-3¾ lbs. per tree but it can be seen that at these limits the number of available trees diminishes rapidly and there is considerable danger of losing precision because of fewer replications.

Naturally, the precision of these experiments could be improved by testing only two treatments instead of four or more. It should of course be realised that a two treatment experiment is only one-eighth as informative as a four treatment one provided significant results are obtained. Nevertheless the two treatment experiment is often useful for a preliminary reconnaissance to compare one treatment with a control. Table XI is a duplication of Table X but it is calculated for two instead of four treatments. The significant differences are smaller but except for special experiments the increase in precision does not appear to outweigh the loss of scope of the experiment.

The results of the covariance analysis on the single tree fields are shown in Table XII. They indicate that the covariance analysis does increase the precision of the experiments but barely to the level of the selection year.

TABLE XII

Covariance Analysis of Single Tree Experiments (Four Treatments)

Significant Differences (P=.05)	Field 5 A		Field 13 A.	
	Lbs. per Tree	Per cent. of Mean	Lbs. per Tree	Per cent. of Mean
1941-2 ...	.56	25.7	.55	27.4
Correlation Coefficient	+ .62		+ .66	
1941-2 adjusted by 1940-1	.44	20.3	.42	20.7
1940-41 ...	.40	19.4	.51	19.5

Conclusions

Certain conclusions can be drawn from these uniformity trials; naturally they apply only to Grenada but may also be of help and interest to investigators elsewhere. The first conclusion is that any experiment in which less than 20 per cent. response is anticipated or required should not be laid out as one experiment on a field of cacao selected at random. It is possible in a few lucky instances to obtain significant differences (at P= 05) of less than 20 per cent. but the findings of these trials indicate that a 20 per cent. difference is the *maximum* precision that can be relied upon. If higher precision is required it is necessary to have an area of more than 2 acres of uniform cacao available, so that a design including numerous plots of reasonable size can be used, and to repeat identical experiments. The results of the repeated experiments may be combined or the most precise ones selected from which to draw conclusions. In all cases it would be necessary to obtain yields for at least one control year since the physical appearance of a field is evidently a poor guide to its variability, and the covariance analysis improves precision when the error is based on sufficient degrees of freedom. If great precision is required the scope of the experiment should be ruthlessly confined to two treatments.

With experiments in which such a high degree of precision is not essential, the important requirement appears to be a large number of replications of each treatment. The replications should be sufficiently numerous to give enough degrees of freedom for the error variance not to be seriously affected by the loss of one or two by the covariance analyses. A definite correlation does exist between yields in consecutive years but with six or less degrees of freedom in the error this correlation is nullified to a large extent. From the little evidence available the covariance analysis appears to be particularly important in the Randomized Block lay-out, so that especially in this type of experiment ample replication must be allowed.

The lay-out recommended for ordinary experiments under ordinary conditions based on the data used in this article is a repetition of Latin Squares. There appears to be no objection to having plots 1/20 an acre in size if sufficient replication is allowed. On a two-acre block thirty-six plots of this size could be laid out in four 3×3 Latin Squares. In experiments with three types of artificial manure and a control it would seem desirable to secure an area of 3-4 acres and lay-out two Latin Squares with half plots similar to those described in this article. This lay out might, admittedly, result in excessive replication in the half plots (32 times) but this excess precision in the half plots could be used to increase the precision of the whole plots by treating the experiment as eight different treatments replicated eight times. These conclusions are of course limited by the designs used in the Grenada experiments; other designs are possible but from lack of data cannot at present be discussed.

Reference

(1) Cheesman, E. E. and Pound, F. J.—*Tropical Agriculture*, Vol. IX., No. 9.

MR. ARTHUR HUBERT CLOUGH

It is with very deep regret that we have to announce that Mr. A. H. Clough, who had just completed his training at this College, was reported "missing, believed drowned" on 3rd August. He was last seen by Mr. L. S. Cobley, another post-graduate student who was near him on the bridge when the ship was hit and sank in 30 seconds. Of the 59 who were aboard only 11 survivors were picked up. Mr. Cobley fortunately managed to get clear and found his way to a raft. He was rescued the next day by an Argentine ship on which he was very kindly treated. He is now safely in a Brazilian port hoping soon to proceed on his way.

Mr. Clough was 22 years old. He was educated at Harvey Grammar School, Folkestone, and the South-Eastern Agricultural College, Wye, where he obtained the B.Sc. degree in Agriculture. In 1941 he joined the Imperial College of Tropical Agriculture as a colonial agricultural scholar and in June 1942 successfully passed the written examination for the Associateship.

Arthur Clough was very highly thought of by both staff and students. He was regarded by his teachers as the best student of his year. Endowed with a pleasant personality he got on remarkably well with everyone including peasants, planters and officials with whom he came into contact during his research activities. He possessed a good physique and displayed great initiative and energy in whatever he did. His hobbies included chess and the violin which he played with much gusto. "Big" as he was familiarly called by his friends was an outstandingly good man in every way and it is a great tragedy that he was unable to show his worth as an agricultural officer in a career in which we all feel he would have gone far.

STUDIES ON AERATION OF CACAO SOILS IN TRINIDAD (I)

BY

H. VINE, H. A. THOMPSON AND F. HARDY
(*Imperial College of Tropical Agriculture*)

INTRODUCTION

BY F. HARDY
(*Professor of Chemistry and Soil Science*)

IN attempting to identify the soil factors responsible for the decline of cacao yields in Trinidad (1), the writer adduced by a process of elimination circumstantial evidence which indicates that deterioration of soil structure is probably the main cause. This in turn suggests that lack of adequate aeration is likely to prevail in some of the poorer-yielding cacao soils, in which case the trees might be unable to obtain necessary supplies of water and nutrients because of faulty root behaviour. It is well known that plant roots are not merely passive absorbing organs, but that they require abundant oxygen so that respiration may proceed, this process being necessary for the generation of energy requisite for active intake of water and nutrients. Thus, in a soil that is badly aerated, new roots may fail to develop and old roots may cease to function, so that no benefit may follow the application of manures. Since deep tillage cannot be applied to the soil of cacao fields occupied by old bearing trees and large shade trees without the risk of injuring their root system, the health and vigour of the trees depends chiefly on the maintenance of a stable porous structure in the soil to considerable depth. This desirable condition might possibly provide the main fundamental difference between a "good" or high-grade cacao soil and a "poor" cacao soil. Indeed in E. M. Chenery's scheme of classification of the soils of Trinidad (2), natural drainage within the soil profile was deliberately chosen as the most important single feature for differentiating cacao soil-types.

So far, no attempts have been made either to study in detail the structure and aeration of the cacao soils of Trinidad or to assess by measurement the degree of natural drainage which these soils present. It was with the intention of obtaining some information on these matters that the preliminary investigations now to be described were initiated.

Methods of Investigation

There are two main experimental procedures for measuring soil aeration; these may be distinguished by the terms "quantitative" and "qualitative". The first aims at determining the natural pore-space of a soil and, if possible, the range and distribution of pores of different sizes, and then tracing the changes in air content of the pores brought about by fluctuating moisture content dependent on rainfall. The second aims at determining periodically the oxygen and carbon-dioxide contents of soil-air by gas analysis, and following the fluctuations of these important factors affecting root activity.

(*A*) *Quantitative Aspect.*

For assessing total porosity (S), the simplest method is to collect, by means of a special soil-sampler, a known volume of soil, weigh it and dry it, then weigh it again and so determine the apparent specific gravity (d_2) as well as moisture content at the time of sampling. The true specific gravity (d_1) of the soil material is separately determined by means of a specific gravity bottle or by an alcohol displacement method. Then

$$S = \frac{d_1 - d_2}{d_1} \times 100 \text{ (per cent.)}.$$

Knowledge of the total porosity value is not sufficient, however, for characterising the soil completely. It is necessary to know also the relative proportion of large ("non-capillary") and small ("capillary") pore-spaces. The first (arbitrarily defined as pores having diameter above 0.01 mm., and therefore easily drained of water by the pull of gravity) are believed to provide the main ventilating channels of the soil. They include minute cracks, old root channels, worm tunnels, etc., in addition to natural interstices into which root-tips may be inserted and there lengthen without restraint. The second (capillary) kind of pores is believed to be too small to permit rapid gas exchanges; the pores serve mainly as storage reservoirs for water.* Their total volume may thus be approximately assessed by measuring the moisture held in the micro-vesicles of soil colloidal matter (3). This may conveniently be done by determining the sticky-point value (P), and correcting if necessary for content of coarse and fine sand, as in the determination of "Index of Texture" (I.T.). Thus, capillary pore space (I.T.)=P—1/5 (coarse *plus* fine sand) (4). Most well-aerated soils have non-capillary pore-space well above 20 per cent. of the total soil volume, but many "single-grain" structured fine-silty soils show values approaching zero. A soil having a large percentage of non-capillary pore-spaces may become so water-logged if the natural drainage is impeded that its actual air content may be diminished to the point where root asphixiation sets in. A completely satisfactory soil should contain adequate supplies of both freely-moving water and air at all times, and should drain rapidly after showers.

* It should be noted that no simple relationship necessarily exists between the magnitude of the total porosity (or even of the non-capillary porosity) and *permeability* of a soil to air and water, since this property is partly decided by the shape and arrangement of the larger pore-spaces and not by their total volume.

(*B*) *Qualitative Aspect.*

Even though a soil may have non-capillary pore-space well above the limit for adequate aeration, namely, about five to ten per cent. of the total soil volume, the *composition* of the air occupying the pores of the soil may be unsatisfactory, in that it may be deficient in oxygen or too rich in carbon-dioxide. These circumstances will affect both root respiration and respiration of the micro-organisms of the soil which, in turn, will affect the breakdown of soil organic matter that has penetrated into the soil, as well as root residues. Consequently, certain organic toxins may be produced which may poison the crop.

It would thus appear that a complete assessment of the aeration of a soil should include both determinations of porosity and of gas composition, which should be carried out periodically and as frequently as feasible, at least through one wet season during which soil moisture contents fluctuate most widely, and root activity is greatest.

The preliminary investigations along the lines indicated above, to be described in this article and in one to follow, were undertaken during 1938-39 by Dr. H. Vine and during 1939-1940 by Mr. H. A. Thompson, post-graduate students of the College, and holders of Colonial Agricultural Scholarships. The information contained in them has been taken from the dissertations presented by these students in partial fulfilment of the requirements of the Associateship of the Imperial College of Tropical Agriculture.

PART I.

POROSITY AND AIR-SPACE IN A CACAO SOIL-TYPE IN TRINIDAD

BY

H. VINE, Ph.D. (London)

(*Former Post-Graduate Student*)

The following article describes the results of certain quantitative studies of soil aeration; the qualitative aspect will be considered in a succeeding article.

Description of Site and Soil

The site of the first series of experiments was part of Field 25, River Estate, the Government Cacao Experiment Station in Trinidad. The cacao trees were 26 years old, and comprised budded or grafted Forastero cacao. The ground is flat but uneven, because the field had been "trenched" some years previously, that is, trenches had been dug between the rows of trees, filled with vegetable waste, and then the soil returned on top. The soil-caps had settled almost to the level of the surrounding land, but the position of the trenches could still be discerned. The rest of the area had been subject to intermittent trampling under the feet of observers during their periodic visits to the area. Hence considerable irregularities in soil compactness were expected.

The soil is alluvial in origin; it belongs to a loamy phase of the *River Fine Sand* soil-type, and is regarded as free-draining (2). It overlies tawny-coloured, uniform, schistose, finely divided river alluvium, derived from Northern Range metamorphic rocks. Texturally, the soil is a fine loamy-sand, containing about 20 per cent. of coarse sand (2.0 to 0.2 mm.), 36 per cent. of fine sand (0.2 to 0.02 mm.) and 44 per cent. of silt and clay. The "sticky point" is about 35 per cent. The colloidal clay content is relatively low and organic matter content, medium-low (about 2 per cent.), though fairly uniformly distributed down to the 12-inches depth.

The yielding capacity of this soil is assessed by the estate manager at about 500 lb. dry cacao per acre; the soil would thus be rated as Grade II cacao soil (2). Its fertility status is not particularly high; potash is the most deficient nutrient.

Experimental Work

EXPERIMENT 1.

The first experiment consisted of determinations of soil porosity at spots where the land appeared to the eye to be undisturbed. Samples were taken with a special standard-volume, cylindrical, brass boring tool, at 0 to 4 inches and 4 to 8 inches depths, at nine (9) different spots within a 6-acre block. Each soil-core, having volume 168 cc., was transferred to a tin tightly fitted with a lid, and subsequently weighed in the laboratory. The samples were then dried in the oven and weighed again to obtain moisture contents. Finally, the true specific gravity of the oven-dried material was determined. From these measurements, the data contained in Table I were calculated. The effect of moisture content, however, has here not been considered.

Conclusions.—The natural porosity of this fine sandy soil apparently varies appreciably around mean values of 48 per cent. for the surface soil and 46 per cent. for the sub-surface, the variation being about ± 2 per cent. (Samples Nos. 8 (A) and 9 (A), and 7(B) and 9(B) lie outside the range of the others, and may be ignored, since they probably represent soil that has been somewhat disturbed.) Measurements of pore-space based on single or a small number of determinations of apparent specific gravity are thus likely to be inaccurate because of soil heterogeneity. Investigations of porosity should therefore involve a large number of determinations before generalisations are attempted.

EXPERIMENT 2.

This experiment resembled the last, except that soil samples were taken at spaced distances between two rows of cacao trees across an old mulch-trench. The results obtained are set out in Table II, in which the condition of the soil is indicated for each sample by a relative term.

Conclusions.—The total pore-space is inversely proportional to the degree of compaction or hardness, as would be expected. At the time of sampling, the actual air-space of the soil (volume

TABLE I

Variation in Porosity in Undisturbed Soil in a Cacao Field at River Estate

Surface Soil (0 to 4 ins.)				Subsurface soil (4 to 8 ins.)			
Sample number (A)	Apparent specific gravity	True specific gravity* (Average)	Porosity (Pore-space; volume per cent.)	Sample number (B)	Apparent specific gravity	True specific gravity* (Average)	Porosity (Pore space; volume per cent.)
1	1.44	2.67	46.0	1	1.50	2.72	44.8
2	1.45	2.67	45.7	2	1.54	2.72	43.4
3	1.36	2.67	49.1	3	1.52	2.72	44.1
4	1.42	2.67	46.8	4	1.45	2.72	46.8
5	1.37	2.67	48.5	5	1.49	2.72	45.4
6	1.34	2.67	49.8	6	1.46	2.72	46.6
7	1.42	2.67	46.8	7	1.31	2.72	(51.8)
8	1.20	2.67	(55.1)	8	1.42	2.72	48.0
9	1.23	2.67	(53.9)	9	1.32	2.72	(51.5)
Means (ignoring values over 50)...	1.40	2.67	47.7 (±2.0)		1.48	2.72	45.6 (±2.3)

*Variation in this value was negligibly small.

TABLE II

Lateral Variation in Soil Porosity and Aeration in a "Trenched" Cacao Field at River Estate

Distance from row of trees (ft.)	Surface Soil (0 to 4 ins.)				Subsurface Soil (4 to 8 ins.)			
	Condition of soil	Total pore-space (Vol.%)	Part occupied* by (a) water (Vol.%)	Part occupied* by (b) air (Vol.%)	Condition of soil	Total pore-space (Vol.%)	Part occupied* by (a) water (Vol. %)	Part occupied* by (b) air (Vol.%)
0 ...	hard ...	43.4	35.2	8.2	hard ...	47.2	30.2	17.0
2 ...	medium ...	45.9	38.8	7.1	hard ...	45.6	30.0	15.6
3.5 ...	soft ...	48.0	42.6	5.4	medium ...	45.2	31.6	13.6
5 ...	hard ...	44.2	33.4	10.8	— ...	—	—	—
6 ...	medium ...	45.5	40.0	5.5	soft ...	53.5	33.8	19.7
11 ...	soft ...	46.2	41.1	5.1	medium ...	46.0	37.8	8.2

* Condition at time of sampling, 15th November, 1939, during a wet spell.

per cent.) apparently ranged from 5.1 to 10.8 (average 7.0) in the surface soil, and from 8.2 to 19.7 (average 14.8) in the subsurface scil. The surface soil actually contained the greater amount of water, doubtless because rain had fallen only a short time previous to the sampling.

When determining air-space and moisture content of soil at any instant, it is evident that great care should be taken to select truly representative spots for sampling, so as to reduce the variation around the means.

Experiment 3.

In order to follow the changes in porosity down the profile, standard-volume depth samples were taken in the smoothed sides of 3-foot pits excavated at two random spots within the site under consideration. Comparable soil samples were also taken for determination of the "index of texture"* which is believed to furnish an approximate measure of the amount of moisture that can be held in the micro-reticulate structure of the colloidal components of the soil, that is, of "capillary pore-space", expressed as volume percentage. The results are given in Table III.

Conclusions.—Each profile shows a marked diminution in porosity with depth. The surface layer differs in the two cases, that of Profile (B) being more porous and "softer" than that of Profile (A), and both would be regarded as having rather high total pore-space. Below the 8-inch depth, the porosity of the soil layers seems to be very similar in the two profiles. Here the

* Index of texture=sticky point *minus* 1/5 coarse and fine sand content (4).

TABLE III

Vertical Variation in Soil Porosity and Aeration in a Cacao Field at River Estate

Lower Depth (ins.)	Profile (A)					Profile (B).				
	Total pore-space (Vol. %)	Capillary pore-space (Vol. %)	Non-capillary-pore-space (Vol. %)	Part occupied* by (a) water	Part occupied* by (b) air	Total pore-space	Capillary pore-space (Vol. %)	Non-capillary pore-space (Vol. %)	Part occupied* by (a) water	Part occupied* by (b) air
4 ...	49	28	21	45	4	56	28	28	26	30
8 ...	51	32	19	40	11	45	32	13	34	11
12 ...	46	35	11	38	8	45	35	10	37	8
16 ...	—	—	—	—	—	—	—	—	—	—
20 ...	43	35	8	36	7	45	35	10	36	9
24 ...	—	—	—	—	—	—	—	—	—	—
28 ...	40	32	8	36	4	43	32	11	34	9

* Condition at time of sampling, (A) 8th and (B) 10th November, 1939, during a wet spell.

TABLE IV

Effect on Aeration of High Soil-moisture Contents during the Rainy Season in a Cacao Field at River Estate

Sampling date (Wet season, 1939)		Rainfall of previous fortnight. (ins.)	Surface soil (0 to 6 ins.)		Subsurface soil (6 to 12 ins.)		Subsoil (24 to 30 ins.)	
Month	Week		Part occupied by		Part occupied by		Part occupied by	
			(a) water	(b) air*	(a) water	(b) air*	(a) water	(b) air*
June ...	2	1.63	31	18	30	15	—	—
July ...	4	3.19	42	7	41	4	—	—
,, ...	6	4.06	40	9	39	6	—	—
,, ...	8	5.69	35	14	36	9	—	—
Aug. ...	10	2.87	37	12	37	8	—	—
,, ...	12	7.19	40	9	37	8	—	—
Sept. ...	14	3.18	44	5	42	3	42	0
,, ...	15	—	40	9	38	7	42	0
,, ...	16	4.48	40	9	38	7	41	1
,, ...	17	—	39	10	39	6	42	0
Oct. ...	18	3.45	38	11	36	9	42	0
,, ...	20	1.90	39	10	34	11	—	—
Nov. ...	22	1.94	40	9	40	5	—	—
,, ...	24	3.89	41	8	40	5	—	—
Dec. ...	26	0.99	41	8	38	7	—	—
,, ...	28	4.56	40	9	39	6	—	—
,, ...	30	0.78	40	9	38	7	—	—
Jan. ...	32	1.73	41	8	38	7	—	—
		Means ...	40	9	38	7	42	0
Total pore-space			49 per cent.		45 per cent.		42 per cent.	
Capillary porosity			28 per cent.		35 per cent.		32 per cent.	
Non-capillary porosity ...			21 do.		10 do.		10 do.	

* Note.—Values for pore-space occupied by *air* :—

(*a*) above 10 per cent., may be regarded as denoting "*good*" conditions of aeration,
(*b*) 10 to 5 do. do. do. "*medium*" do. do.
(*c*) 5 to 0 do. do. do. "*bad*" do. do.

magnitude of the so-called "non-capillary pore-space" (comprising the larger spaces and channels having diameters greater than 0.01 mm.) averages about 10 per cent., which, on suggested standards, would be considered to lie on the border-line of adequacy for drainage facility. This implies, that when penetrating soil, water partly occupies these larger spaces (having already completely filled the "capillary spaces"), aeration may be seriously curtailed, and undesirable physiological conditions, which adversely affect root activity, may set in.

Thus, at the time of sampling (early November, 1939), the average air-space of the soil layers below the 8-inch depth was only about eight per cent., which implies that the circulation of soil gases had become somewhat impeded. Actually, the moisture content of the soil at this time was relatively low, considering it was the height of the rainy season, so that aeration was actually much better than at other times during the rainy period.

EXPERIMENT 4.

The possibility that continuous rains might appreciably diminish, or even obliterate, the free air-space of the soil by filling the non-capillary pores and channels, suggested that a test might be made by using a series of periodic soil moisture determinations which were being carried out at the site of these experiments in connection with certain other ecological studies undertaken by Dr. E. C. Humphries. Accordingly, standard-volume soil samples were taken at two depths (namely 0 to 6 inches and 6 to 12 inches), corresponding with the depths of moisture sampling, fortnightly or weekly from 17th June, 1939 to 13th January, 1940. During September, 1939, special samples were also collected at greater depth, namely, 24 to 30 inches. The soil moisture samples were composites of cores taken at ten spots at least. The values used for total pore-space and for capillary and non-capillary pore-space were means of a number of determinations believed to furnish a reliable measure of the average conditions within the area under consideration. The relevant data are presented in Table IV.

Conclusions.—The data indicate that aeration in the surface 6-inch layer of soil was only medium-good at this site throughout the rainy season of 1939; the values obtained would be regarded as lying on the border-line of adequacy. At no time evidently were the non-capillary pore-spaces entirely empty during this wet period; usually they were more than half-full of water. The capillary spaces throughout were full of water, the colloidal components being completely saturated.

The aeration of the second 6-inch layer of soil was even worse. The subsurface soil is more compact than that of the layer above, and its non-capillary porosity is one-half as great. Usually, however, only a little less than one-third of the non-capillary pore-space was occupied by water, the rest being air, though the *total* amount of air-space, reckoned as volume per cent. of soil, was appreciably less than that of the top 6-inch layer.

Lower down the profile, aeration apparently deteriorated rapidly. Although no records were taken of the conditions in the layer immediately below 12 inches, the layer between 24 and 30 inches was evidently completely devoid of air throughout the 5-week period of measurement in the middle of the rainy season, and possibly this condition prevailed for several weeks, both before and especially after this period.

During the first week of September, 1939 (week 14), aeration was particularly poor, lowest values being recorded at this time for the two upper layers, the soil of which was nearly completely saturated with water with almost entire exclusion of air.

These results are somewhat unexpected considering the fact that the River Fine Sand soil-type is generally regarded as one of the most freely-draining soils in Trinidad (2).

Comparison with other Data.—By way of contrast, it may be noted that Leather (5) has measured very much greater amounts of free air-space in an alluvial soil at Bihar in India, even during the monsoons. The lowest value recorded by him was 15 per cent. by volume for the top four feet of soil, though on one occasion the air-space at 4½ feet was only four per cent.

Stephenson and Schuster (6) have recently classified soil aeration as "*good*" if the air-space volume lies between 20 and 10 per cent. at "field moisture capacity" (that is, when the capillary pore-spaces are replete with water, probably corresponding numerically with the Index of Texture value), and "*poor*" if it is less than five or six per cent. Values ranging from about six to twelve per cent. they regard as denoting "average" aeration. In a highly productive orchard soil of Oregon (namely, Newberg Loam), the air-space (non-capillary pores) to a depth of eight feet lay between 14 and 20 per cent., whereas in a heavy unproductive soil (Sites Clay), it dropped from ten per cent. in the upper three feet to *zero* below the 4-foot level.

According to these standards, the degree of aeration of the River Estate soil during the rainy season would be considered to be definitely low, having only "average" value in the upper 12-inch layer, and apparently quite unsatisfactory in layers below 24 inches. This being the case, it is interesting to speculate on the conditions that may possibly obtain in those cacao soils of Trinidad that are regarded as naturally poorly-drained, as for example, certain compact, heavy, acidic clays, such as abound in river "vegas" occupying considerable areas in the Northern Plain, and in parts of the undulating Clay Belt in the Southern Plain, where cacao has failed badly in recent years. It is hoped that the investigation described in this article may later be extended to include some examples of these heavy clay soils.

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TOMATO CULTIVATION ON THE COLLEGE FARM

BY

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Tomatoes are a dry season crop on the College Farm. The heavy rainfall of the wet season is inimical both directly and indirectly to their productivity. The direct effect has not been investigated, but indirectly heavy rainfall favours a great increase in gall midge infestation. The larvae of this midge cause flower shed.

1. Nursery Management

(*a*) *Varieties.*—In 1934 a varietal experiment (6) failed to pass the Z test; there may or may not have been differences in yield between the varieties concerned, namely Marglobe, Bonny Best and Red Rock. Marglobe fruits were, however, considered preferable for export, they were easier to pack, being more uniform in size and shape than fruits of the other two varieties. They also gave better slices when cut for they were less creased at the stem end.

(*b*) *The Nursery.*—Usually seed obtained from the United States is broadcast on beds about the beginning of November. In 1941 (7) the rate of sowing was one ounce of seed to every 18 square feet of seed bed. One ounce of seed (9,000 seeds) produced an average of 4,140 seedlings two days after germination and 965 transplants five weeks later. After sprinkling soil thinly over the seed the surfaces of the beds are slightly consolidated by beating them gently with a piece of board. The beds are then watered and covered with coconut leaves. Seedlings appear about three days later, whereupon the shade leaves are removed to structures above the beds, until the seedlings are strong enough to withstand heavy rain. The beds are watered in the morning and evening but care is taken not to overwater them for fear of increasing "damping off". When one or two weeks old, seedlings are pricked out four or five inches apart in beds manured with compost and artificials, to prevent overcrowding and to reduce losses from "damping off". It is advisable to shade seedlings for two or three days after pricking out. About one or two weeks after this operation the beds are worked with a trowel fork to break their surface "pan". It has been customary in the past to water sparingly during the last week before transplanting to "harden" the seedlings. In 1941 (7) this was proved unnecessary, for it was found impossible to produce "tender" seedlings, even by shading, manuring and watering copiously.

2. Field Cultivation

(*a*) *Transplanting.*—In early December the field in which the crop is to be grown is given ten tons of compost per acre; it is then ploughed and ridged. The ridges are finished with hand hoes. Plants are grown on ridges as a precaution against heavy rainfall in late December and in order to make furrow irrigation possible, later in the season. Plants are transplanted in the late afternoon and watered afterwards.

(*b*) *Planting Distances of Staked Plants.*—When tomato plants are grown from seed of the same origin in the tropics and in North America, they yield much less in the tropics. A consideration which governs the spacing of tomatoes is that the less productive the type, the closer should be the spacing. Experiments in spacing on the College Farm have proved the usual American planting distance of two by three feet for staked plants to be too great for our conditions. In 1934 (6) staked plants, pruned to a single stem, grown on ridges three feet apart, gave significantly greater yields per unit area when set 1½ feet apart on the ridges than when two or three feet apart, while plants two feet apart gave significantly greater yields than those at three feet. In 1942 (7) both staked and unstaked plants, on ridges three feet apart, gave significantly heavier yields when at one foot than when 1½ or two feet apart, while those at 1½ feet yielded more than those at two feet. In North America rows of tomato plants must be set at distances which will allow mechanical cultivation to be carried out. It is because of this that row distances are so uniform over that continent. On the Farm, however, distances need be only enough to allow for ridging and the use of the hand hoe between the rows.

(*c*) *Staking and Planting Distances of Unstaked Plants.*—Bamboo stakes six to eight feet long are placed firmly in position four to six inches away from plants soon after transplanting. Plants are tied to these stakes with string, fibre or strips of banana midrib.

In 1933 and 1934 staked and pruned plants were matched against unstaked and unpruned plants in two experiments (8) (5). both of which failed to pass the Z test, thus there may or may not have been differences in yield between the treatments. In 1942 (7) staked and pruned plants yielded a significantly greater weight of fruit than unstaked and unpruned plants; three spacings: one by three feet, 1½ by three feet and two by three feet, were equally represented in both treatments. In this experiment the plants were irrigated four times. Rows of unstaked plants proved to be too closely spaced for them to escape damage from irrigators and irrigation water. This damage resulted in reduction in yields and premature death of some plants. On 28th March there was a significantly greater number of blank plant sites in the unstaked plots. This factor contributed to the low yield of the unstaked plants.

In the 1942 spacing experiment (7) the treatments included unstaked plants as well as staked and pruned plants. In America unstaked plants always require more room than staked and pruned plants; it was therefore expected that the wider the spacing the greater would be the yield of the unstaked plants. It is suggested that this was not so, partly because irrigation damage removed only an excess of the plant population from the closely spaced plots, but caused a deficit in the widely spaced ones.

(*d*) *Pruning, Tying and Topping.*—Early in January all side branches of staked plants are pruned and the plants are, at the same time, tied to the stakes. Care is taken to tie inflorescences away from the stakes to avoid the bruising of the fruit against them. These operations are carried out once a week from then on. When plants begin growing out of reach at the age of four months, they are topped, and a side branch is allowed to develop in place of the main stem growing point.

(*e*) *Mulching.*—In 1942 (7) a mulch of 8.8 tons per acre of dried cane trash was included in the experimental lay out. It was applied at the end of January after the field had been irrigated twice. The mulch variance did not pass the F test, thus mulching may or may not have affected the yield of plants.

(*f*) *Miscellaneous Cultural Practices and Harvesting.*—The stands of experimental plants have received varying amounts of irrigation depending on the severity of the dry season. Thus in 1934 (5) they received one irrigation, in 1935 (4) five irrigations, while in 1942 (7) four irrigations, amounting to 13.4 inches of water, were required.

Weeds are not plentiful during the dry season, so only one or two weedings are necessary. Should transplanting occur when the ground is soggy, additional hoeings or inter-cultivations are essential to break the concreted condition of the dried ridges.

In all experiments fruits were harvested in the mature green stage and their pedicels clipped off to prevent bruising during storage. Fruits were then divided into damaged and undamaged lots. The undamaged or exportable fruit were classified into three grades: Fruits of (i) diameter greater than 2¾ ins. (ii) diameter between 2¾ and 2½ ins. (iii) diameter between 2½ and 1¾ ins. Those with diameter less than 1¾, together with damaged fruit, were classified as unexportable fruit.

3. Artificial Manuring

Three manurial experiments, in 1933 (8), 1934 (5) and 1935 (4), failed to yield information concerning the manurial requirements of the crop. The variances for treatments did not pass the F test. In 1942 (7) the crop was manured with artificials, in the proportions of three parts of nitrogen to four parts of phosphorus pentoxide to three parts of potassium oxide, at the rate of 1,260 lb. per acre. This was placed in holes six inches away from the plants in three monthly applications; the first soon after transplanting. Each plant in the experiment received an average of two ounces of artificials.

4. Yields and Profits

Year	Total yield tons per acre.	Yield of exportable fruit T.P.A.	Tons of fruit actually sold.	Received from sale. $ p.a.	Cost per acre. $	Profit $
1933 ...	3.8	1.4	?	400	200	200
1934 ... Ref. 5	4.3	?	3.9	436	203	233
1934 Ref. 6	2.8	2.3	2.4	209	194	15
1935 ...	?	?	4	315	233	82
1942 ...	3.5	1.4	2.6	589	503	86

5. Root Studies

In 1942 (7) root studies, in which Weaver's trench method was used, showed that the roots of both staked and unstaked plants, five months old, extended to a depth of five feet. Unstaked plants had a greater root development than staked and pruned plants.

6. Pests and Diseases

(*a*) *Pests.*—The important pests of the nursery are mole crickets and flea beetles. In 1934 (6) a 1 to 32 mixture of Paris green and flour, used as a dust, controlled flea beetles. In the field the gall midge (*Contarinia lycopersici*) oviposits in unopened buds, and the developing larvae cause the buds to drop (3). In 1942 (7) unopened buds were inoculated with one to three gall midge larvae, in an attempt to discover whether these

larvae were responsible for a well-defined type of damage, known to occur early in the fruit's development. Mature fruit suffering from this damage have characteristic deep wounds, which sometimes nearly divide the fruit in two. 73 per cent. of the inoculated buds withered and fell; the remaining 27 per cent. developed into undamaged fruit; it was considered that the larvae in these jumped out immediately after inoculation. In no case did an inoculated flower develop into a damaged fruit. Gall midge larvae are not therefore responsible for "early" damage. Fruit borers (*Prodenia* and *Heliothis* species and another unidentified small, transparent web-spinning caterpillar), are usually controlled by hand-picking; so also is the hornworm (*Protoparce* species), which defoliates plants. Other field pests include *Cerambycid* beetles (*Alcidion* species)—which kill plants by tunnelling up the stems; Coreid fruit suckers, flea beetles and mole crickets.

(*b*) *Diseases.*—Briant (2) and Baker (1) have written articles on tomato diseases in Trinidad. In 1934 (6) and in 1942 (7) sclerotial wilt or "Southern blight" (*Sclerotia Rolfsii*), was the commonest wilt in the field. Ageing is accelerated by eel worm (*Heterodera radicicola*), which is extremely common, and leaf spots (*Alternaria* and *Phoma* species).

In 1942 (7) it was shown that the curve of growth cracking, expressed as a percentage of the weight of each harvest, was a reflection of the curve of water received by the field and the yield curve. The latter approximates to the curve of the speed of growth of mature plants. In other words predisposing conditions for growth cracking are: (*a*) Rapid growth after slow, (*b*) continuous rapid growth.

In 1942 (7) results suggested that the fruit of staked and pruned plants suffered more from physiological diseases (growth cracking and blossom end rot), than did the fruit of unstaked plants. It was thought to be the result of an unbalanced water relationship, which was due to a greater exposure of staked plants to drying conditions; rather than to the foliage of unstaked plants conserving water by mulching the soil under these plants. The fruit of unstaked plants suffered more from miscellaneous types of damage (mainly scarring) disease (in the field) and sun scald. In 1934 (8) a fruit disease termed "centre rot" was reported; no external symptoms are exhibited by fruit suffering from this disease.

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NORMAL AND ACCELERATED EROSION

BY

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[*This note forms the first part of an article, mainly describing land erosion in the Piedmont area of South Carolina, U. S. A., which was presented at a symposium held at the U. S. National Academy, Washington, D.C.*:—EDITOR.]

The geologic norm of erosion.—The twin concepts "normal erosion" and "accelerated erosion," commonly considered to include all erosion past and present, are disarmingly simple. If interpreted literally, they suggest that accelerated erosion was unknown before the coming of man, and conversely, that the changes brought about by man merely quickened the pace of certain normal processes. Both of these interpretations are misleading.

Realizing that normal erosion was a flexible quantity varying widely with meteorological, tectonic, and other influences, Lowdermilk, in 1929, set up an idealized standard of natural erosion, aptly named the "geologic norm of erosion". Erosion was considered in the broadest possible sense and was made to include the mass-movement processes many of which are highly effective in the natural denudation of the lands.

Transition from the geologic norm of erosion to present-day erosion has involved far more than simple acceleration. Extensive changes of balance in the effectiveness of mass-transport and mass-movement must have taken place. On the natural landscape, streams carved their channels much as they do to-day, but the percentage of permanently-flowing streams was probably larger, and the percentage of ephemeral and intermittent drainages smaller than now. There was generally a good plant-cover in humid

lands and, so far as that covering was complete, slope-washing was prevented. The amount of soil-removal by slope-washing or sheet-erosion must have been small. Owing to good infiltration into deep mellow soils rich in humus, mass-movements of soil down slope by creep must have been highly effective. Streams received much of their load from creeping valley slopes, but because of an equable hydrologic regimen resulting from good ground-storage, streams carried their loads with relatively small fluctuations in transporting power.

Despite the rapid destruction brought on by clearing the lands for cultivation, it is evident that soil-erosion is not altogether a new process introduced by man. Very slow erosion of surface soil is an essential pedogenic process, and must have been active long before the first crude tillage of the soil. Under natural conditions, too, local and occasional events temporarily induced serious acceleration of soil-removal. Strokes of lightning in the dry forest, devastating blights, uprooting tornadoes, and sudden downpours of tropical cyclones all can penetrate the land's vegetal defence and expose the soil to accelerated erosion.

Interrelation of vegetal and soil-profile development.—Protection by plant-cover retards the removal of surface soil and gives time for the soil-forming processes to work to completion. Without vegetation's aid to weathering and to the chemical and biological processes of soil-formation, mature soils could not develop. Together, mature soil and vegetation reduce run-off. Stems, roots, and plant-litter retard surface flow, and, from the leaves, moisture is returned to the air by transpiration.

Climate, working through its control of the plant-cover, produces great regional variations in mature soils. In humid and sub-humid lands, where the surface is normally well covered with vegetation and vegetal litter, deep soil-profiles can form. In regions too arid to have adequate plant-protection, gullying, sheet-washing, and wind-erosion have always been active. Without mantling vegetation, there can be no soil-material on slopes steeper than the angle of repose, and even on more gently sloping land the products of weathering wash or blow away almost as quickly as they are formed.

Changes in erosion brought about by man's use of the land.—Normal soil-development, normal erosion, normal balance of the several processes of denudation, and even normal sculpturing of the surface of humid lands, then, can take place only with the presence of a normal vegetal cover. Man, by removing the natural vegetation, has destroyed the balance of all of these relations. In clearing the forests and baring the land for cultivation, man has added his destructive powers to those of nature. Run-off has been greatly increased, both in rate and amount and, as a result, streams now flow less regularly, their load is carried fitfully, and their floods reach higher crests.

Changes wrought by man have increased sheet-erosion, rilling, gullying, and wind-erosion. These processes truly have been accelerated. The natural downhill creep of the soil, however, is now of smaller relative consequence than under natural conditions. It is probably smaller in absolute value too, owing to the general reduction in ground-moisture.

Recent work on geomorphology of accelerated erosion.—Recent studies by the Climatic and Physiographic Division of the United States Soil Conservation Service have increased our knowledge, not only of the dynamics of accelerated erosion, but of the whole relationship of the present accelerated cutting to erosion in the past. Field-work in the Piedmont of South Carolina, for example, has helped to explain the rapid erosion of abandoned lands and has outlined the life-cycle of the characteristic deep, caving-walled, Piedmont gully.

On agricultural lands, the periodic reworking of the surface soil helps materially to prevent concentrated erosion. Soil is still removed by sheet-erosion and rilling, but listing and cultivating tend to equalize surface irregularities and prevent gully formation. When land is abandoned and this equalizing process ceases, rills persist and rapidly grow to gully size.

REVIEW

The South African Sugar Year Book, 1941-42

South African Sugar Journal, Durban, price 5 shillings.

We have recently received the 12th and latest, edition of the *South African Sugar Year Book*, which is the reference book and guide to the South African sugar industry. Of special interest to sugar growers generally will be Mr. G. C. Stephenson's article on "Some Aspects of the Sugar-Cane Variety Position in Mauritius" and Mr. Ody Lamborn's contribution on "Sugar and the World War". It will be recalled by readers in the British West Indies that Mr. Stephenson was at one time a student at the Imperial College of Tropical Agriculture, Trinidad and later became Assistant Geneticist at the W.I. Cane Breeding Station in Barbados before finally taking up his present post of geneticist at the Sugar-Cane Research Station, Mauritius. The Editor is to be congratulated on having maintained in the present edition of the Year book the high standard of previous issues which from time to time have been reviewed in these columns.

The Editor is prepared to consider signed articles for publication in *Tropical Agriculture*. Such articles should normally vary between 1,000 to 6,000 words and may be illustrated if desired.

CHEMICAL NOTES

(Compiled by the College Department of Chemistry and Soil Science)

Experiments on Fertilizers at the Macaulay Institute

At the Macaulay Institute for Soil Research, Aberdeen, various composts were tested as soil amendments in place of leaf mould or dung, and it appeared that the kind of compost is of less importance than the nutrient contained in it. Town-refuse dust (after heating with or without materials like beach leaves and peat for four months) produced toxic effects on horticultural crops grown in boxes.

The conditioning of mixed commercial fertilizers with peat litter, ground dolomite, sand and ground mineral phosphate in the proportion of 10 per cent. showed that after nine months' storage the mixture with peat was much superior to the others in physical condition.

The value of crushed biotite schist as a source of potash has been investigated on lime and unlimed soil. The biotite used contained only about three per cent. of K_2O, so that grinding and other costs for application of a reasonable amount of potash are high. It was found, however, that the ground schist had an appreciable residual value in the second year after application.—(*Soils and Fertilizers*, Vol. 5, No. 2.)

* * *

Effects of Layered Cultivation

Deep cultivation in layers (whereby the surface horizon is buried and the sub-soil brought to the surface, the process being reversed after a few years) produces a stable crumb structure in the topsoil in the first year, after which the structure gradually disintegrates. After two years the crumb structure of the former topsoil is largely restored, but the crumbs are not water-stable. Other important agricultural properties showed similar tendencies—an improvement in the new topsoil in the first year followed by a deterioration in subsequent years, and little change for better or worse in the old topsoil.—(*Soils and Fertilizers*, Vol. 5, No. 3.)

* * *

Heavy Soils and the Quality of Tobacco

On account of the reputed bad quality of tobacco grown in heavy soils, experiments were carried out in South Australia where the growth of tobacco in a sample of heavy soil known to produce poor tobacco was compared with that in a sample of heavy soil known to yield good tobacco. Despite the high nitrogen content of the former soil, low-nitrogen plants were obtained under optimal conditions. With deficient water, however, the nitrogen content of the plants was very high and ripening was much delayed. Probably the cause of bad quality in heavy soils is to be sought in a combination of soil and climatic factors, among which water supply may play an important part.—(*Soils and Fertilizers*, Vol. 5, No. 2.)

Nitrate Fertiliser Additions to Waterlogged Soils in relation to Oxygen Deficiency

Application of nitrogen fertilisers had no beneficial effects on water-logged soils, nitrate being harmful to avocados and ammonia to grapefruit under these conditions. Accentuation of water-logging injury by the nitrogen fertilisers may be due to osmotic effects, to toxic action of nitrite or other reduction products of nitrate, or to stimulation of organisms which attack the roots; the amount of nitrate in drainage water after the heaviest treatments was the toxic limits of these plants when grown in solution or sand-culture.—(*Brit. Chem. Phys. Abstrs.*, B.III, p. 226.)

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Some Results of Termite Activity in Thailand Soils

In many parts of Thailand termites are of considerable benefit to farmers. The millions of moulds built by termites furnish small plots of modified soil which when utilized properly are useful for growth of trees and of "upland" crops in paddy districts, thus permitting a considerable degree of diversification in cropping and diet. The nature and distribution of termite moulds, and physical and chemical analyses of ten termite moulds from widely different parts of Thailand and of their associated normal soils are reported in *Thai. Sci. Bull.* 3, No. 2. The most striking chemical feature of the mould soils was the accumulation of calcium carbonate in the base of the moulds, although the normal soils of the places where the moulds were sampled were moderately to strongly acid. Near the place where calcium carbonate concretions ("gravels") were first recognized as having come from termite moulds no deposits of calcium carbonate were known within several miles. The soils of termite moulds usually had a higher air-dry moisture content, their pore space was usually higher, and some other physical properties showed higher values than did normal soils. The higher fertility and consequently the agricultural importance of the moulds are due to their higher plant-nutrient content and pH, the better moisture relationships, and to the fact that the upper portions of the moulds are above the water level on the padi land.

Destruction of the moulds is seldom advisable. When moulds are broken down and the earth spread about the former site, the productivity of the land remains very irregular and the growth of tobacco may be prejudiced. In one district, however, other fertility relationships seem to prevail. Recommendations are made as to the method of complete clearing of termite moulds, should this be deemed advisable. No mechanism is suggested to account for the differential accumulation of calcium in the moulds or for the other chemical and physical soil differences revealed.